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LTE Simulator Implementation and Performance Analysis of Cellular Network

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Abstract: ***LTE (Long term evolution) represents an emerging and promising technology for providing broadband Internet access. New Scenarios for LTE can be implemented by analyzing the output performance using LTE Simulator. Unfortunately, at the present, to the best of our knowledge, no open source simulation platforms, to evaluate the performance of the entire LTE system, are freely available. LTE-Simulator, an open source LTE-Simulator has been conceived to simulate uplink and downlink scheduling strategies in multi-cell/multi-users environments taking into account user mobility, radio resource optimization, frequency reuse techniques, Adaptive Modulation Coding (AMC) module, and other aspects very relevant for industrial and scientific communities. The effectiveness of the LTE simulator has been tested and verified considering (i) the software scalability test which analyzes both memory and simulation time requirements (ii) the performance evaluation of a realistic LTE network providing a comparison among well known scheduling strategies such as professional fair(PF), Exponential Professional fair(EXP), Modified Longest Waited Delay First(MLWDF).***

Keywords: LTE, Simulation, Performance Evaluation, New algorithm implementation and Modeling.

1. Introduction

To face the ever growing demand for packet-based mobile broadband systems, the 3GPP has introduced LTE (Long Term Evolution) specifications as the next step of the current 3.5G cellular networks. An enhanced access network (i.e., the E-UTRAN, Evolved-UMTS Terrestrial Radio Access Network) and an evolved core network have been defined. At the present, more than 20 cellular operators worldwide, representing together more than 1.8 billion of the total 3.5 billion mobile subscribers in the world, have already stated a commitment to LTE and more than 35 million LTE subscribers are foreseen by 2015. In fact, the most important vendors of mobile communication equipments have implemented their own simulators.

Moreover, other simulators, developed in academia-industrial co operations, can be purchased using a commercial license, and their source codes are not publicly available. Mat lab-based LTE simulator has been proposed, implementing a standard compliant LTE downlink physical layer with Adaptive Modulation and Coding (AMC), multiple users, MIMO transmission and scheduler. Unfortunately, albeit it is open source and freely available, it does not consider relevant

Aspects of LTE simulation, such as realistic applications, a complete LTE protocol stack, and multi-cell environments with uplink flows System level simulator for LTE networks has been proposed as a supplement of the previous one, in order to support cell planning, scheduling, and interference. However, it does not support a complete LTE protocol stack, uplink flows, and bearer management. To bridge this gap, herein, we present an open source framework to simulate LTE networks, namely LTE-Sim, able to provide a complete performance verification of LTE systems. LTE-Sim encompasses several aspects of LTE networks, including both the Evolved Universal Terrestrial Radio Access (E-UTRAN) and the Evolved Packet System (EPS).

In particular, it supports single and multi-cell environments, QoS management, multi-users environment, user mobility, handover procedures, and frequency reuse techniques. Three kinds of network nodes are modeled: user equipment (UE), evolved Node B (eNB), and Mobility Management Entity/Gateway (MME/GW). Several traffic generators at the application layer have been implemented and the management of data radio bearer is supported. Finally, well-known scheduling strategies (such as Proportional Fair, Modified Largest Weighted Delay First, and Exponential Proportional Fair, AMC scheme, Channel Quality Indicator (CQI) feedback, frequency reuse techniques, and models for physical layer have been developed. It is important to note that features covered by LTE-Sim will allow both researchers and practitioners to test enhanced techniques for improving 4G cellular networks, such as new physical functionalities, innovative network protocols and architectures, high performance scheduling strategies and so on. LTE-Sim is freely available under the GPLv3 license.

Any new algorithms which are used in wireless communication system to improve the spectral efficiency, transmitted power and overall performance of LTE network can designed, developed, implemented and output results are evaluated through simulations using this LTE Simulator depending upon requirement. The main goal of this simulator is develop new functionalities and improve the performance of LTE network as per the Standards of 3GPP Protocol Stalk defined by ITU.

2. LTE-Simulator Working Methodology For Analyzing Scenarios

A. Software Design

There are four main components The Simulator, The Network Manager, The Flows Manager, and The Frame Manager.

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1. Simulator creates a new event and inserts it into the calendar, Executes an event. Starts/ ends the simulation.
2. Frame Manager Handles the start and the end of the Lte frame structure handles the start and end of the sub frame.
3. Flows Manager handles applications, creates applications.
4. Network Manager Creates UE device, creates LTE cell , Updates the UE position , Handles the hand over procedure, Implements Frequency Reuse Techniques
5. Using this LTE simulator we can evaluate the performance of entire LTE Network
6. Using LTE Simulator we can perform simulations of our own Scenarios depending on our requirement.
7. We can analyze the performance of any algorithm which is used in the LTE network (4g).
8. This LTE Simulator supports all the 5Layers physical(PHY) , medium access control (MAC), Radio Link Control (RLC) , Packet Data Control Protocol(PDCP), Radio Resource Control (RRC)layer protocol stalk of OSI Model
9. A Simulation Scenario is composed by several objects, modeling the main elements of an LTE system. Each of them can issue, if needed, a new event using a Simulator::Schedule ( ) method, to enable a realistic interaction among nodes.
10. The Calendar sorts events in a chronological order, according to their timestamps. Events scheduling is handled by the Simulator class.
11. In details, at the beginning of each simulation, the Calendar is populated by only three events: (i) the start of the simulation, using the Simulator::Run ( ) method; (ii) the start of the Frame Manager, using the Frame Manager::Start Frame ( ) method; (iii) the end of the simulation, using the Simulator::Stop ( ) method.

The Calendar will be populated by other events generated by LTE system elements which constitute the simulated scenario, e.g., Application::Create Packet ( ), Network Node::Send Packet Burst ( ), ENodeB::Resource Allocation ( ).

3. Protocol Stalk Implemented

LTE-Simulator implements several functionalities of both user plane and control-plane LTE protocol stacks. To this aim, the Protocol Stack class has been created as a container of RRC, PDCP, and MAC entities. An instance of this class, namely m protocol Stack, has been defined for each device.

Furthermore, as proposed in a RLC entity has been created for each dedicated radio bearer. The RRC Entity manages downlink and uplink dedicated radio bearers for a given device. It interacts with the classifier in order to classify a packet into a proper radio bearer. The PDCP Entity provides the header compression of packets coming from the upper layer that will be en queued into a proper MAC queue.

The RLC Entity models the unacknowledged data transmission at the RLC layer. We have chosen to implement the unacknowledged mode for the RLC because it represents the most used data transmission mode, especially by delay sensitive and error-tolerant application (such as VoIP and video streaming). The most important functionalities we have defined for the RLC layer are the segmentation and the concatenation of service data units.The MAC Entity provides, for both UE and eNB devices, an interface between the device and the PHY layer designed to delivery packets coming from the upper layer to the PHY one and vice versa. Moreover, into this class the AMC module is also defined. EnbMACEntity class adds further functionalities, Such as uplink and downlink packet schedulers, to the eNB. An example of the interaction among the entities included in the implemented protocol stack is illustrated in Fig. it shows the packet path starting from the application layer and following the user plane protocol stack.

The LTE packet is modeled by the Packet class. Three important variables are defined for the packet object, m time Stamp, m size, and m packet Headers. The m time Stamp variable represents the instant the packet is generated at the application layer. This value is used to compute one-way packet delay (it could also be used for statistical purpose and by scheduling strategies). The m size and m packet Headers variables represent the packet size and the list of protocol headers that have been added to the packet, respectively. When the packet is created, m size is equal to the amount of data generated by the application layer. As soon as a new header protocol is added to the packet, m size is updated according to its size. The Protocol Stalk implemented is shown in fig1. Consisting 5 Layers Physical, Mac, RLC, PDCP and RRC of OSI Model.

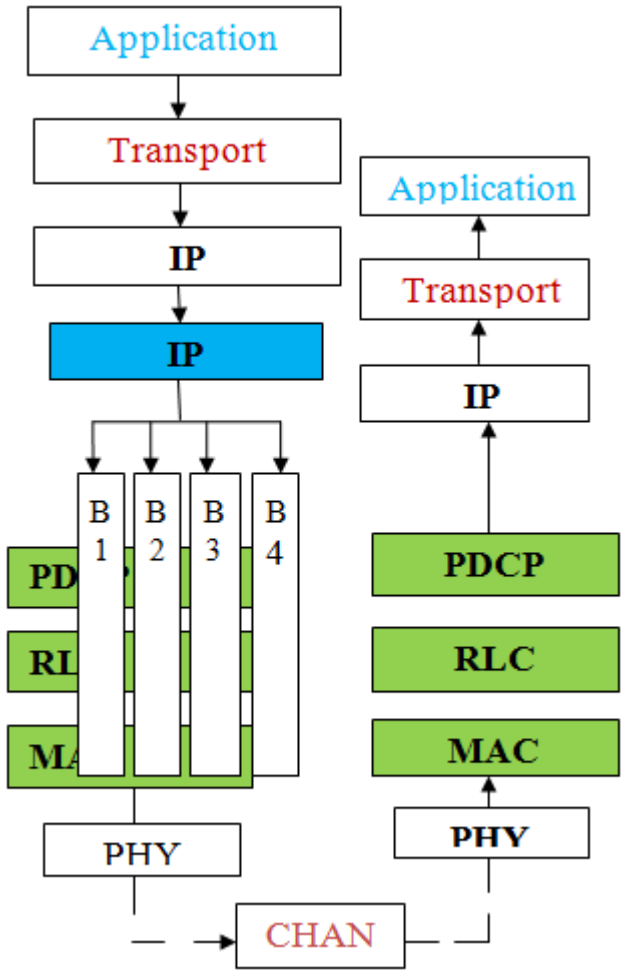


Figure 1: Stalk Implementation

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The LTE packet is modeled by the *Packet* class. Three important variables are defined for the packet object: m time Stamp, m size, and m packet Headers. The m time Stamp variable represents the instant the packet is generated at the application layer. This value is used to compute one-way packet delay (it could also be used for statistical purpose and by scheduling strategies). The m size and m packet Headers variables represent the packet size and the list of protocol headers that have been added to the packet, respectively. When the packet is created, m size is equal to the amount of data generated by the application layer.

As soon as a new header protocol is added to the packet, m size is updated according to its size. In the current release of only the UDP protocol has been developed at the transport layer. However, it is possible to implement other transport protocol (i.e., TCP), extending the Transport Layer class. During the simulation, the application layer creates packets which are passed to the UDP and the IP protocols. As we have explained in Sec. IV-A, an IP-based packet classifier is used to map IP data grams to radio bearers. Each bearer maintains its own FIFO (First in First Out) transmission queue, using the MAC Queue class. When an IP packet is en queued, a PDCP header is added. Since the PDCP protocol provides a header compression functionality using the robust header compression (ROHC) protocol, the packet size is updated in order to compress RTP/UDP/IP Headers to 3 bytes. Finally, when the packet is de queued, CRC trailer and RLC and MAC headers are added.

4. Channel Structure And Resource Management

4.1 Basic Network Topology

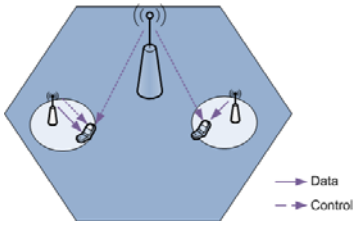


Figure 2: Single cell Topology

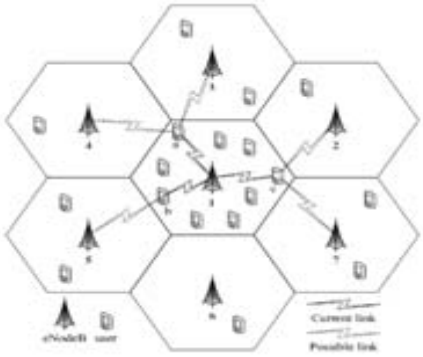


Figure 3: Multi cell Topology

The network topology is composed by a set of cells and network nodes (including eNB, one or more MME/GW, and UEs), distributed among cells. All the methods for the creation and the management of the network topology is provided by the Network Manager component. A LTE cell, implemented by the Cell class, is identified by a unique identifier (ID). Its attributes are the radius and the position defined in a Cartesian system. For each kind of LTE network node, a dedicated class has been developed, extending the basic Network Node class (i.e., ENodeB, User Equipment, and MME-GW classes). Each network node is identified by a unique ID and its position in a Cartesian system is also defined. Support for several functionalities of both user and control plane protocol stacks is provided by the Protocol Stack class, developed as a container of RRC (Radio Resource Control), PDCP (Packet Data Control Protocol), and MAC entities. The eNB performs radio resource management for the evolved radio access. Both downlink and uplink scheduling strategies are defined into its MAC entity. In particular, downlink and uplink schedulers are defined into the M downlink Scheduler and m uplink Scheduler variables, respectively. As previously mentioned, for eNB and UE devices, an instance of a PHY object, namely m phy, has been defined. PHY objects, moreover, are attached to a LTE channel, modeled by the Channel class. This class manages the transmission through the physical channel of the actual packet among the attached physical entities, implementing also a propagation loss model. The PHY object has been developed: for providing an interface between the LTE device and the channel; for storing and managing information about the radio channel (such as bandwidth, list of available sub-channels for both downlink and uplink); and for offering an access to the radio channel to simulate the packet transmission and reception.

4.2 Bandwidth Manager

Further details about the implemented channel and physical Models are provided in Sec. V. CQI reporting is another important feature performed by the UE. In particular, LTE-Simulator supports also the CQI reporting feature, i.e., the UE estimates channel quality and converts it in a set of CQI feedbacks reported to the eNB. Our simulator supports both periodical and aperiodical CQI reporting and both full band and wide band reporting modes. During the simulation, each eNB maintains the list of UEs associated to it, storing, for each of them, the ID and the latest CQI feedbacks. Furthermore, eNB and UEs are aware of the LTE cell they belong to. In fact, each UE keeps up to date the ID of the cell it belongs to and the ID of the eNB it is registered to.

5. Frame structure used

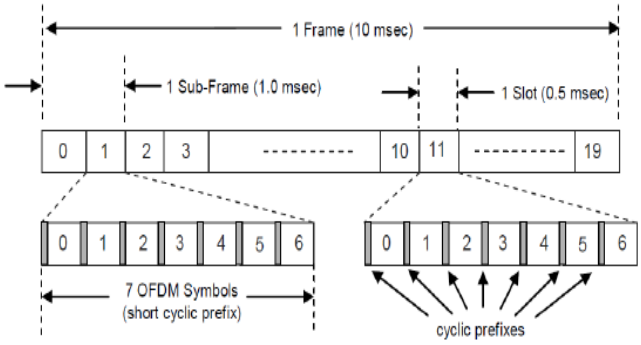


Figure 4: Frame Structure

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LTE-Simulator supports two frame structure types proposed in for the E-UTRAN. The first one is defined for FDD mode and it is called frame structure type 1. The second one is called frame structure type 2 and is defined for TDD mode. For the frame structure type 1, the bandwidth is divided into two parts, allowing downlink and uplink data transmissions, simultaneously in the time. For the frame structure type 2, the LTE Frame is divided into two consecutive half-frames, each One is lasting 5 ms. As shown in fig 4.

Moreover, a special sub-frame in each half-frame is reserved for other purposes and is not used for data transmission. In a real LTE network, this sub-frame is used to send downlink and uplink pilot symbols, separated by a Guard Period. According to, Tab. II reports seven implemented uplink-downlink configurations of type 2 (TDD) frame. We note that sub-frames 0 and 5 are always reserved for downlink transmission. The frame structure and the TDD frame configuration have been defined in the Frame Manager. During the simulation, the Frame Manager schedules LTE frame and sub-frames and decides, according to the frame structure, if a sub-frame will be used for the uplink, for the downlink, or for both of them.

6. Results And Discussion

Languages Used are Linux Operating System, C ++ Coding, Tcl Shell Scripting. Three Different scheduling algorithms are implemented each producing, The Output trace is displayed directly during the execution of the simulation, each scheduling algorithm produce different outputs, we can compare them and select best algorithm.

As we are using LTE SIMULATOR both transmitter and receiver outputs in the same screen, as shown in fig 5. whatever the data packets which are transmitted will be received at receiver end with or without delay each having source and destination id's.

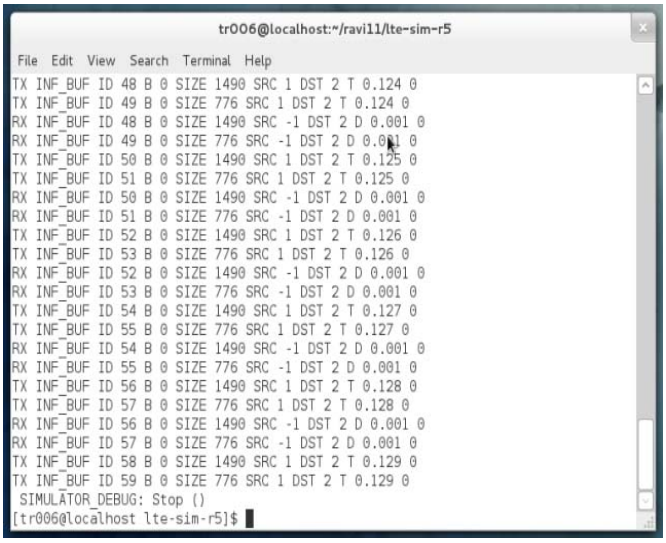


Figure 5: Simulation Results

In further improvement of the paper we are planning to implement error correction algorithm in Physical layer. Which is tough task performing introduction of redundancy code at transmitter end and cross checking same at receiver end depending on status of data it will send positive and negative acknowledgements to the transmitter and finally soft combining is done, allowed the data packet for further decoding.

7. Graphical Outputs

By Running LTE Simulator for calculated duration (start time) and (stop time) various graphical output waveforms are generated from Fig 6 to Fig 15 as shown for all the 3 scheduling algorithms PF,EXP,MLWDF. From which comparison of efficiency is done for schedulers.

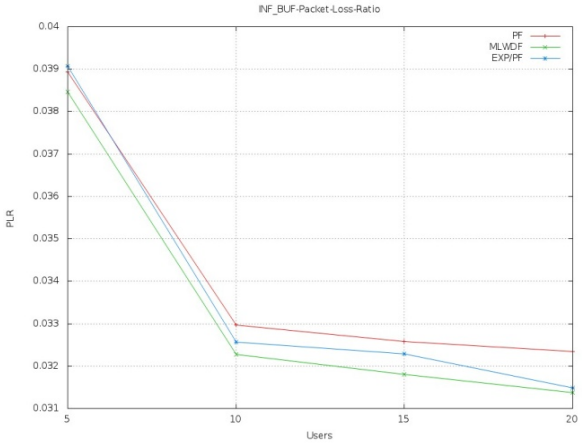


Figure 6: Infinite Buffer Packet Loss Ratio

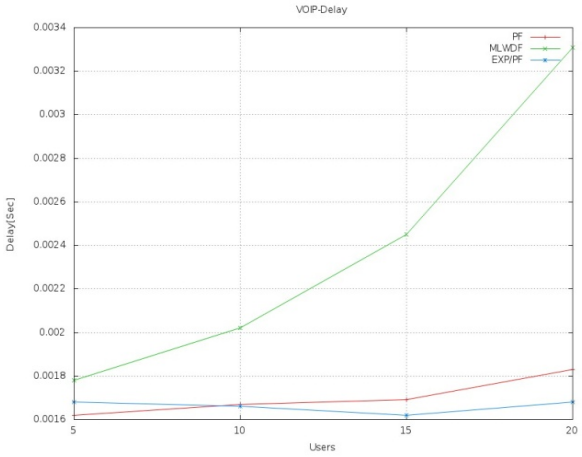


Figure 7: VoIP Delay

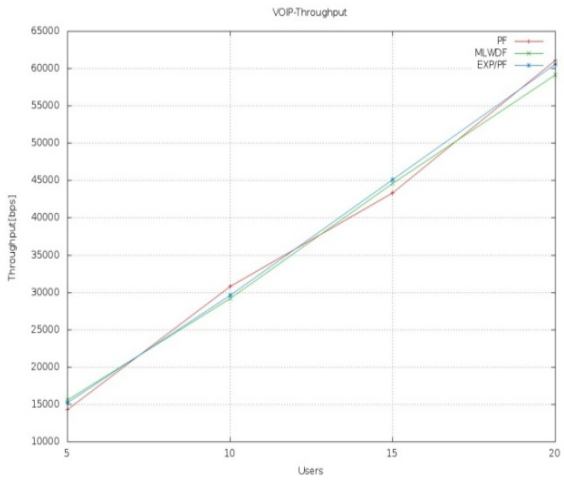


Figure 9: VoIP Throughput

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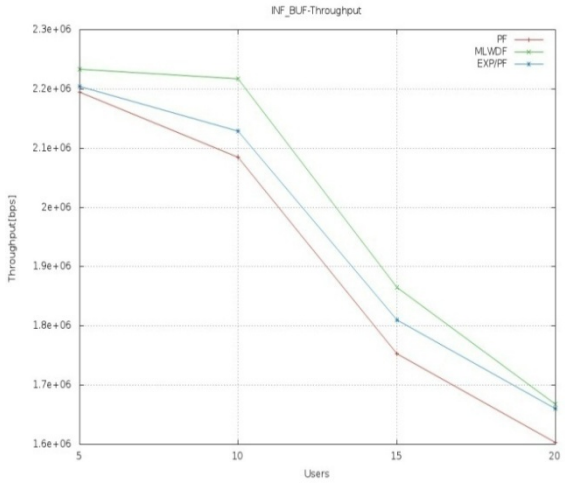


Figure 11: Infinite Buffer Throughput

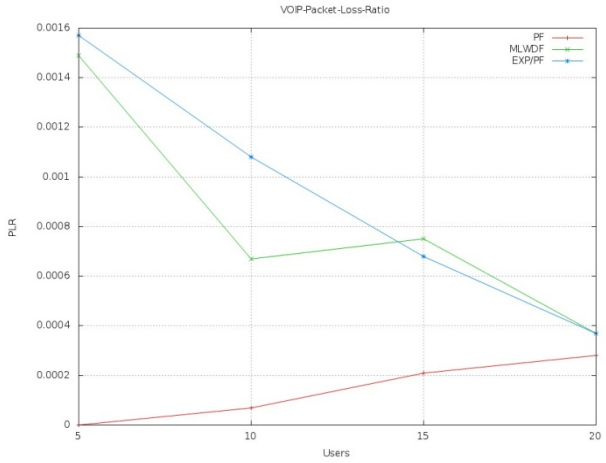


Figure 12: VoIP Packet Loss Ratio

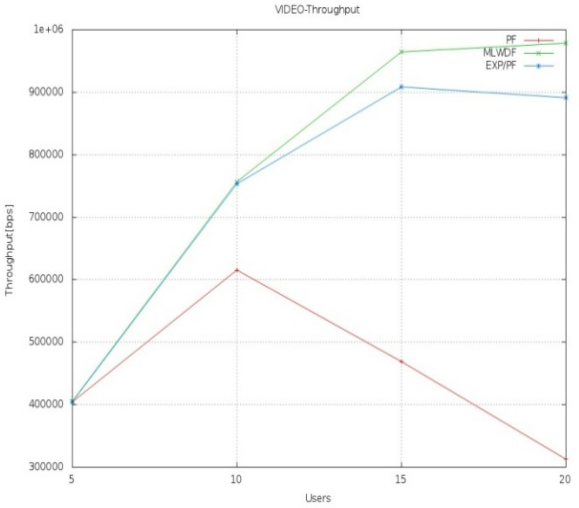


Figure 8: VoIP Throughput

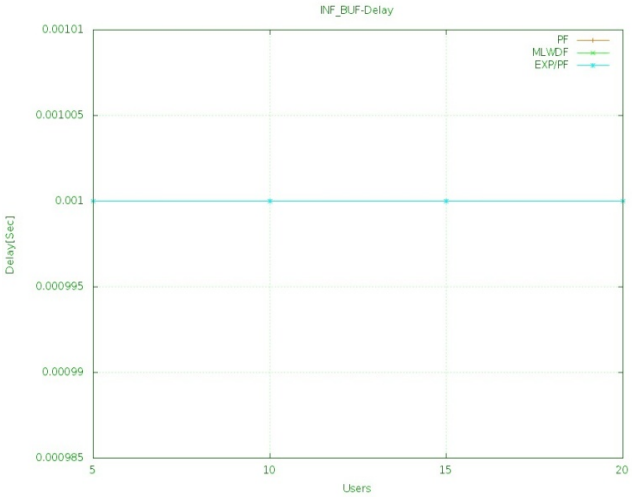


Figure 13: Infinite Buffer Delay

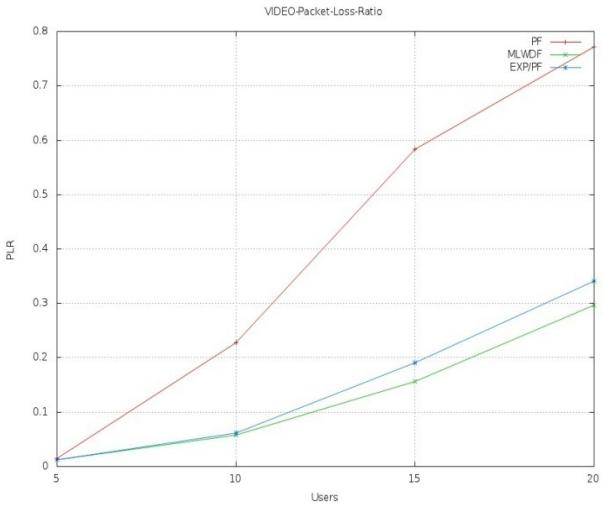


Figure 10: Video Packet Loss Ratio

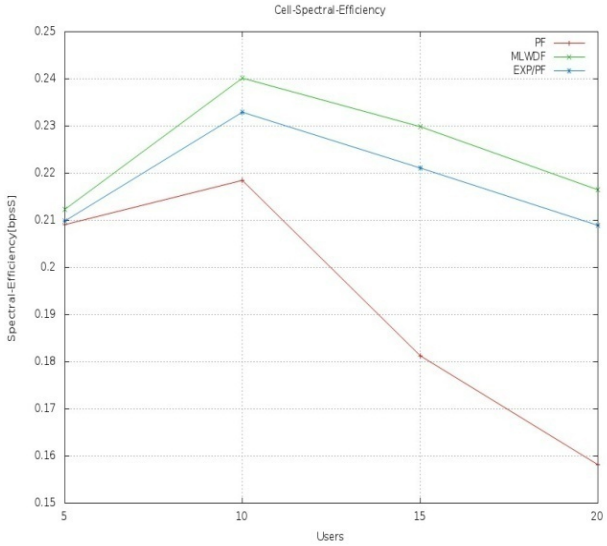


Figure 14: Cell Spectral Efficiency

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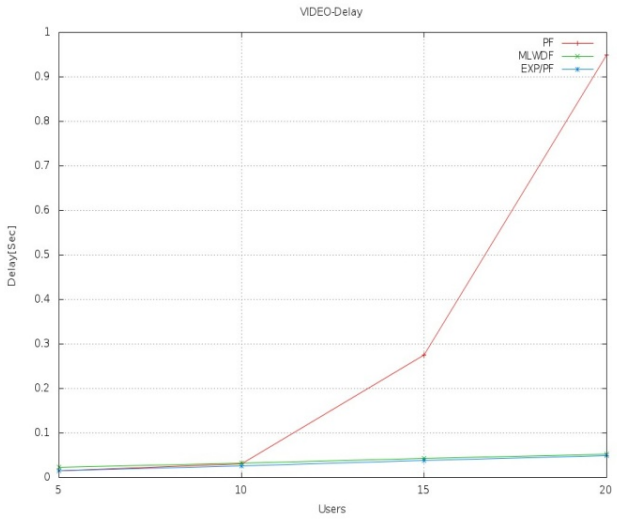


Figure 15: Video Delay

8. Conclusion

In this paper a new open source framework namely LTE-Simulator, has been implemented to study the output performance of LTE Cellular Network. Both for Developed and New Scenarios, of LTE network simulation and analysis of output performance are carried out.

New Error test model is implemented for checking the error caused during the transmission of data packets from transmitter to receiver.

Features covered by this simulator will allow both researchers and practitioners to test enhanced techniques for improving 4G cellular networks, such as new physical functionalities, innovative network protocols and architectures, high performance scheduling strategies, and so on. The open nature of this software can allow people interested in research in this field to contribute to the development of the framework, furnishing a reference platform for testing and comparing new solution for LTE systems. Effectiveness of the developed simulator has been verified with several simulations to study the scalability and the performance of the framework. In this paper we have verified all the six scenarios for both single cell and multi cell environments, we have developed one new scenario simulated and verified outputs. The specialty of this paper we can any number of users there is no limitation for only memory size has to large and as the number of users and simulations increases the time taken to perform simulations will increase.

9. Future Scope

- New cell topology Scenarios (micro cell, macro cell, Femto cell, etc) development, Implementation, simulation and outputs results verification for complex scenarios has to be carried out.
- New scheduling algorithms has to be developed, implemented and outputs results verification should be carried out
- New functionalities, algorithms for LTE protocol stalk like HARQ has to be developed for good spectral efficiency according 3GPP Specification.
- More New functionalities for protocol stalk layers (PHY, MAC.RLC, PDCP, and RRC) have to be developed according to 3GPP standards.

References

[1] C. Mehlf¨uhrer, M Wrulich, J.C. Ikuno, D. Bosanska, and M. Rupp, “Simulating the Long Term evolution physical layer,” in Proc. Of the 17th Signal Processing Conf. EUSIPCO, Glasgow, Scotland, 2009
[2] J. C. Ikuno, M. Wrulich, and M. Rupp, “System level Simulation of LTE networks,” in Proc. of IEEE Veh. Technol. Conf., VTC Spring, Taipei, Taiwan, May 2010.
[3] R. Basukala, H. M. Ramli, and K. Sandrasegaran, “Performance analysis of EXP/PF And M-LWDF in downlink 3GPP LTE system,” in Proc. of First Asian Himalayas Int. Conf on Internet. AH-ICI, Kathmandu, Nepal, Nov. 2009.
[4] Gennaro Boggia, Pietro Camarada, “On accurate simulations of LTE Femto cells using an open source simulator” EURASIP J. Wireless Comm. Oct 10 2012.
[5] Alexandrescu, Modern C++ Design: Generic Programming and Design and Patterns Applied. Addison-Wesley Professional, 2001.
[6] “Video trace library,” [OnLine] Available: http://trace.eas.asu.edu/.
[7] C. Wei, Z. Lili, and H. Zhiyi, “Second-order statistics of Improved Jakes’ models for Rayleigh fading channels wireless Communications,” in Proc.of Int. Conf. on Networking and Mobile Computing, WiCom, Shanghai, China, Sep. 2007, pp. 1108 –1111.
[8] M. S. Alouini and A. J. Goldsmith, “Area spectral efficiency of Cellular mobile radio Systems,” IEEE Trans. Veh. Technol., vol. 48, no. 4, pp.1047 –1066, Jul. 1999.
[9] 3GPP, Tech. Specif. Group Radio Access Network Requirements for Evolved UTRA (E- UTRA) and Evolved UTRAN (E-UTRAN), 3GPP TS25.91

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